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THE LATE TRIASSIC SNYDER QUARRY: A BRIEF HISTORY OF DISCOVERY AND EXCAVATION

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Abstract—Following Mark Snyder's discovery of NMMNH locality 3845, the "Snyder quarry," in June, 1998, we directed no fewer than five major and several minor excavations at the quarry, recovering more than 60 jackets and hundreds of isolated elements from July, 1998 to May, 2001. After the famous Ghost Ranch *Coelophysis* quarry, this quarry appears to be the richest single Chinle bonebed, as it yields more specimens per square meter than the contemporaneous Canjilon quarry or, indeed, any other quarry for which detailed excavation records exist.

Keywords: Snyder quarry, Late Triassic, discovery, excavation, history

INTRODUCTION

For both of us, our first experience at the Snyder quarry was a welcome opportunity to tangle with a rich lode of fossil vertebrates. From the first glance at shiny black bones with tinges bordering on metallic purple, it was clear that these bones were special, different from any other locality in the Chinle. Indeed, upon every return to the Snyder quarry its richness continues to amaze—here is a remarkable snapshot of a Late Triassic ecosystem. This paper establishes the chronology behind paleontological effort at the Snyder quarry (NMMNH locality 3845; Fig. 1), providing a detailed explanation of when and how the quarry was excavated and when particularly significant discoveries were made.

Institutional abbreviations: GR = Ruth Hall Museum of Paleontology, Ghost Ranch, Abiquiu, NM; MDM = Mesalands Dinosaur Museum, Tucumcari, NM; NMFOP = New Mexico Friends of Paleontology (NMMNH paleontology volunteers); NMMNH = New Mexico Museum of Natural History, Albuquerque, NM.

CHRONOLOGY

In this section, we establish the history of discovery and excavation at the Snyder quarry (Table 1). After the introductory paragraphs, this section is divided into sections on the excavations led by Heckert (1998-2000) and Zeigler (2000-2001). To clarify which author is making a particularly salient point, we use our initials (ABH and KEZ) in those places where it is not clear which author is using the personal pronoun.

Although the Snyder quarry has occupied a substantial portion of the NMMNH's field efforts since Mark Snyder discovered it in 1998, it must in fairness be stated that at least one party had stumbled upon it previously (Table 1). In 1995 or 1996, Steve Fowler of Santa Fe brought some remarkably well-preserved, black bones of Triassic animals from "National Forest Service land near Ghost Ranch" to the NMMNH. Steve himself did not find these bones, he merely brought them in at the request of a father and son from Los Alamos (S. Fowler, pers. comm., 1999). In a phone conversation with Fowler in 1999, ABH determined that the bones in question did indeed come from the Snyder quarry. Unfortunately, Fowler was unable to remember the name of the family that gave him the bones to bring in to NMMNH, and we have since lost contact with him as well.

Why were these bones lost/misplaced/ignored? One of us (ABH) was very interested (KEZ was not in NM yet), but confused them with other bones from the Chama basin that were eventually sent to another paleontologist. Mistakenly believing that the Snyder quarry bones were no longer at NMMNH, they were in fact forgotten.

In early May, 1998, NMMNH volunteer Warren Slade led an NMFOP trip (including ABH) to northern New Mexico. For two days we explored Permian and Triassic strata, visiting known localities and

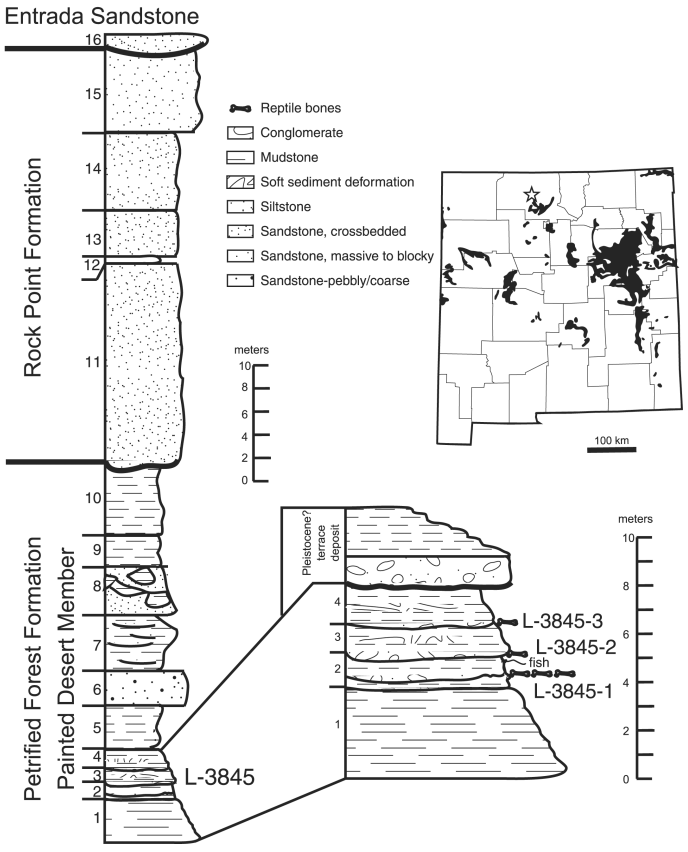

FIGURE 1. Index map showing location of the Snyder quarry site in north-central New Mexico, distribution of Triassic outcrops (from Heckert et al., 2000), and stratigraphic section at the quarry.

prospecting for new ones. Fatefully, on May 2, 1999, we would go down the "Monastery Road" to extensive Painted Desert Member badlands several miles (km) from the highway. There all we found were a few unionid bivalves and a green horizon that looked promising for paleobotanists, but that did not contain vertebrates. Thus, twice that day we drove right past an inconspicuous outcrop, north of the road, that was to become the Snyder quarry.

Whenever he worked at the quarry, Mark Snyder was always asked "how did you find this place?" The following is a condensed version of that story. In June, 1998, Mark had convinced Michael, his brother, and Mary, his sister-in-law, to take him to Ghost Ranch. There they spent a

TABLE 1. Timeline of paleontological effort and discoveries at the Snyder quarry

1996-1996: First black bones brought to the NMMNH by Steve Fowler. These bones include a scute identified as *Desmatosuchus*

June 17, 1998: Mark Snyder visits Ghost Ranch with brother Michael and sister-in-law Mary, discovering the site when dispatched by Alex Downs (Ghost Ranch) to look for fossils of off Ghost Ranch lands.

June 28, 1998: ABH meets Alex Downs and goes to the site

July 7-9, 1998: ABH, Alex Downs, and Adrian Hunt supervise preliminary excavations as part of Ghost Ranch's "Digging dinosaurs at Ghost Ranch" program. Jackets 1-4 collected and brought to the NMMNH with much loose material. ABH measures a miniature stratigraphic section through the quarry (assisted by F. Therrien). By the end of this dig we are aware that there are several theropod elements preserved at the quarry.

July 24-26, 1998: ABH leads first NM Friends of Paleontology (NMFOP) dig to the Snyder quarry, collecting jackets 5-8. Articulated semionotid fish is found near top of "first fining-upwards sequence." First time that Snyder himself is able to join the NMMNH for the excavation.

September, 1998: NMFOP volunteer Larry Rinehart checks in on the quarry while in the area, discovering a partial decapod crustacean in the spoil pile (see Rinehart et al., 2003).

May 13-31, 1999: ABH leads first major NMFOP effort at the Snyder quarry. Highlights include: first use of bulldozer to clear overburden, first phytosaur skulls discovered, first specimens of *Typothorax coccinarum* found, jackets 9-32 collected, first theropod skull found, over 1500 hours of volunteer effort poured into the quarry. Stratigraphic section from the quarry to the Entrada Sandstone measured with S.G. Lucas.

June, 1999: Rogue volunteer collects jacket 33 and delivers it to NMMNH.

September 17-21, 1999: ABH leads NMFOP effort to recover a large phytosaur skull that was left after the spring dig. This is KEZ's first visit to the quarry. Large phytosaur skull is in jacket 37, jackets 34-41 collected

May 23-June 9, 2000: ABH and KEZ co-lead another major excavation kicking off the most intensive summer of excavation recorded there thus far. Bulldozer and miniature backhoe (Terramite) used to remove additional overburden. Jackets 42-48 collected. Other highlights include: several more phytosaur skulls revealed, first associated clusters of *Typothorax* scutes discovered, fault running through quarry first documented, neighboring sites at the same stratigraphic level discovered.

June 13-18, 2000: KEZ leads NMFOP "detail dig." In addition to continued collecting (including jacket 49), KEZ and S.G. Lucas measure four detailed "microsections" through the quarry. Other highlights include the discovery of a tree that hydraulically affected deposition and KEZ's further development of taphonomic hypotheses.

June 21-July 5, 20: KEZ leads NMFOP in field course at the Snyder quarry. June 21-23, crew prospects in an ~400 m radius around the quarry. July 3-5, crew excavates jackets 61 and 62, as well as several individual fossil elements.

couple of days wandering around looking for fossils. On a Tuesday morning, they found a few scraps of bone and delivered them to Alex Downs of the Ruth Hall Museum of Paleontology at Ghost Ranch. When Snyder persisted and asked about additional places they could prospect, Alex suggested the badlands down Monastery Road in the same general area that the NMFOP had prospected earlier that year. As Alex will readily admit, he really just wanted to get Snyder "out of his hair" and figured that, even though most of the outcrops off of Monastery Road were on Forest Service land, Snyder probably would not find anything (nobody else ever had), and there was no harm in letting him look around there (Downs, pers. comm.).

As Snyder tells it, Michael and Mary had packed up their bags and checked out of the Abiquiu Inn and were nowhere near as enthused as he was about more time on the outcrop, but Michael reluctantly headed out of Ghost Ranch and away from Albuquerque, and towards Monastery Road. Sensing that they had had their fill of paleontological prospecting, Mark saw a nondescript outcrop similar to those at Ghost Ranch just north of Monastery Road, and hoping to preserve marital bliss, saw that it provided a quick opportunity to look for more fossils. Michael and Mary agreed and they parked and walked down into the wash while Mark made a beeline for the base of the hill. There he found nothing but loose and weathered rock. Undaunted, he began to sift through the loose talus with his hands, uncovering bone within minutes, including fragments of a *Desmatosuchus* scute. He and Michael then dug through the spoil for more and then followed the bone fragments up to a single layer in the rock. A few minutes later, very much against Mark's wishes, they returned to the car and drove back to Albuquerque.

Fortunately, they did tell Alex the location of their find. Alex took a break a couple days later and went out to the site they described, but found only a few pieces of carbonized wood. When he told Michael that all they had found was wood, Michael actually drove up to the site, pulled a small phytosaur sacral centrum from the producing horizon, marked the horizon and left the centrum at Ghost Ranch for Alex. At that point, Alex was convinced, and when he found out from other Ghost Ranch personnel that the University of New Mexico, not the Forest Service, owned the land, he called one of us (ABH), who then arranged to meet with Alex and see the site first-hand.

Snyder Quarry Excavations Led by Heckert

On June 28, 1998, while returning from a fossil excavation in the San Juan Basin for NMMNH, I (ABH) detoured to Ghost Ranch to meet Alex Downs and see the new locality. Alex took me out to the site Mark's brother Michael showed him, and I was immediately impressed. I found the volume of overburden daunting, but I was positively stunned by the quality of preservation. Indeed, the color and texture reminded me of the bones I had seen once at the NMMNH and I scribbled the following thoughts in my field notebook later that day:

> I was excited immediately because the vertebra Alex showed me was identical in preservation to the material @NMMNH collected by Steve Fowler.
>
> W/in minutes of arriving at the site I was sure we'd rediscovered Fowler's locality. Given the proximity to Arroyo Seco, it is possible that this is one of Baldwin's sites from the 1870s.
>
> ABH 98-24 Just N of Monastery road in S-facing sheer cutbank wall, in bonebed conglomerate approx. 15 ft above arroyo floor. I am sure this is Fowler's locality.
>
> Some test pits revealed the presence of bone as much as 100' from the main site.

Alex offered to have the Ghost Ranch summer program "Digging Dinosaurs at Ghost Ranch" help out in early July, and I readily agreed. Alex had already lined up Adrian Hunt (then of the Mesalands Dinosaur Museum in Tucumcari) to help out with the class, and it yielded 14 raw but enthusiastic volunteers. At Alex's invitation, I came up again on July 6, and worked with him and Adrian and this crew on parts of July 7, 8, and 9, removing much overburden, cutting a bench to stand on while we worked on the quarry, and making four small jackets. One of these held a partial theropod ischium expertly reliefed out *in situ* by a 14-year-old named Jonathan. This effort was important because it was the first time we confirmed the extent of the site and the presence of theropod dinosaurs at the Snyder quarry. Indeed, these excavations, while very limited in scope, revealed that the Snyder quarry was, in fact, every bit as rich as one could hope. The discovery of dinosaurs, which are normally rare in the Chinle, was a particular bonus. Also during this trip I measured a microstratigraphic section at the quarry, identifying what I took to be three fining-upwards sequences, each approximately 1.5-m-thick, at the bonebed and succeeding levels. This section occurs frequently in the literature as the "blown-up" portion of the larger measured section from the quarry area (Fig. 1).

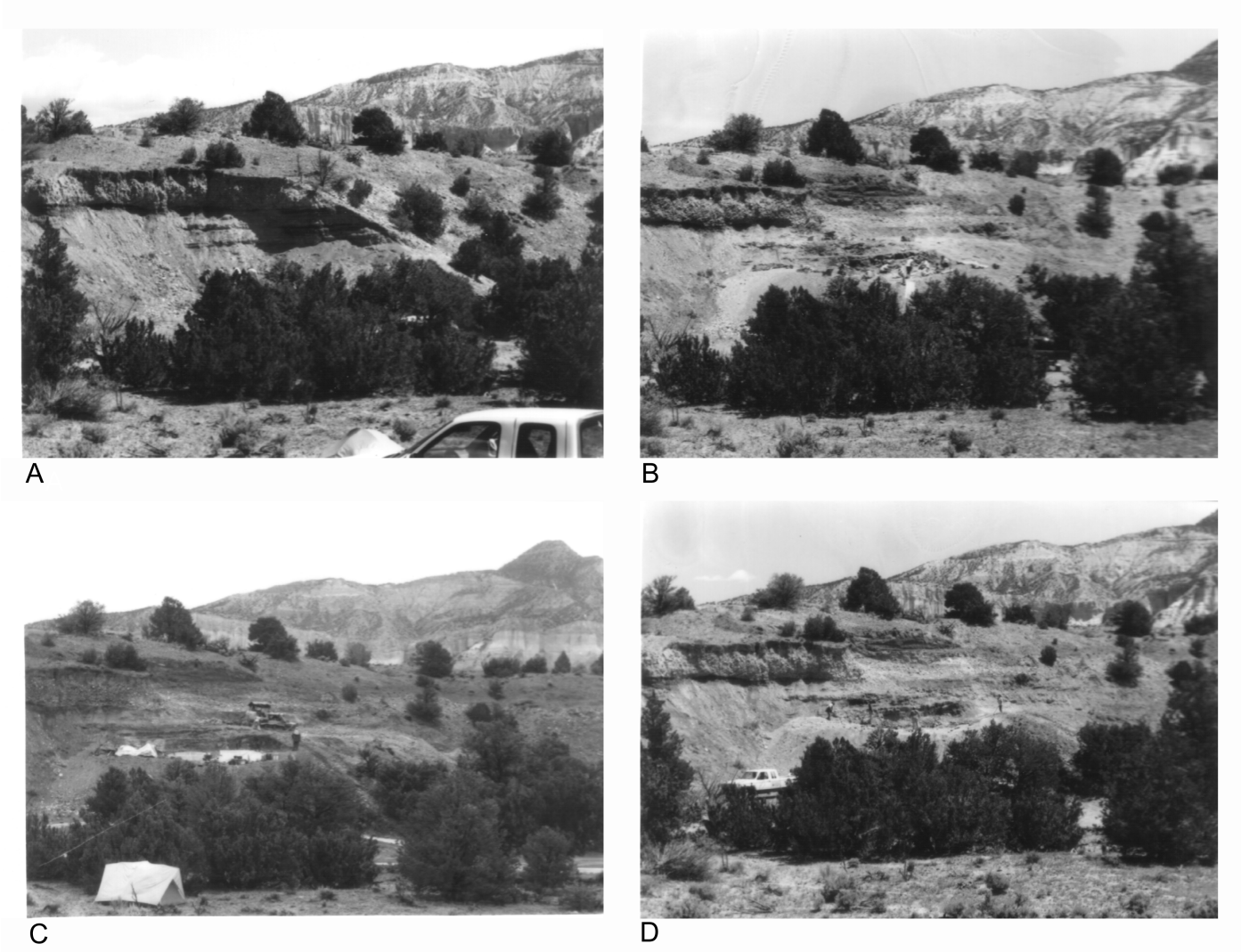

FIGURE 2. Snyder quarry excavations in 1999. **A**, quarry as it appeared prior to bulldozing, 13 May, 1999, **B**, quarry on 18 May, 1999, **C**, second round of bulldozing, 24 May, 1999; **D**, temporary closing of the quarry at the conclusion of the May dig, 31 May, 1999.

The first wholly NMMNH operation directed at the Snyder quarry was July 24-26, 1998. This was the first time we actively sought to remove overburden overlooking the southwestern portion of the quarry and make a reasonable platform for excavating jackets. Snyder himself flew out from San Diego to pitch in, and was immediately set to work in the quarry. In spite of some truly epic rainstorms, hail, a damsel in distress who wandered into camp during one of these storms, and other complications, we extracted four more jackets, one with a theropod sacrum, and verified that the site was worthy of a truly monstrous effort. During the initial removal of overburden, NMFOP member Scott Sucher discovered a partial semionotid fish skeleton in fine-grained deposits overlying the second bone-bearing horizon. Maddeningly, in spite of the volume of material we have removed since that time, we have never found another articulated fish specimen.

The Snyder quarry entered the scientific literature in the spring of 1999. At the annual spring meeting of the New Mexico Geological Society, I presented an abstract detailing our preliminary results (Heckert et al., 1999a). That abstract was published shortly thereafter in *New Mexico Geology*.

A monstrous effort was mounted the next year. April, and even early May, are too unstable from a weather perspective to work at the Snyder quarry. Mountain storms sweep the Chama basin often in the early spring, and snow is still possible, even likely, in very early May. New Mexico's summer monsoon can come early to the Chama basin as well, providing daily thunderstorms, some with hail, as early as mid-June. Accordingly, I scheduled a two week/three weekend dig for mid-late May (May 13-31). This was, at the time, the single largest, continuous paleontological operation mounted by the NMMNH. On the first day, S.G. Lucas and I measured a stratigraphic section from the quarry all the way up to the Middle Jurassic Entrada Sandstone. That section is a fixture in the literature now, as it is immortalized in the "outcrop map and generalized stratigraphic section" figures, usually as figure 1, of every publication on the quarry (Fig. 1). Twice during that dig I hired Ghost Ranch's bulldozer to remove the treacherous ancestral Chama River deposits and their widow-maker cobbles overhanging the quarry, as well as much of the remaining Chinle overburden (Fig. 2A-B). However, the sheer volume of material removed by the bulldozer resulted in an incredible pile of debris over the 3-m-high face of the quarry. Thus, during the first weekend of the dig a veritable army of NMFOP volunteers, as many as 18 at a time, spent more than two days uncovering the quarry after the bulldozer removed the overburden. During this part of the excavation, we began to refer to the different bone-producing horizons (basically channel-fills), in ascending stratigraphic order, as 3845-1, 3845-2, and 3845-3. These labels appear on the "blown up"

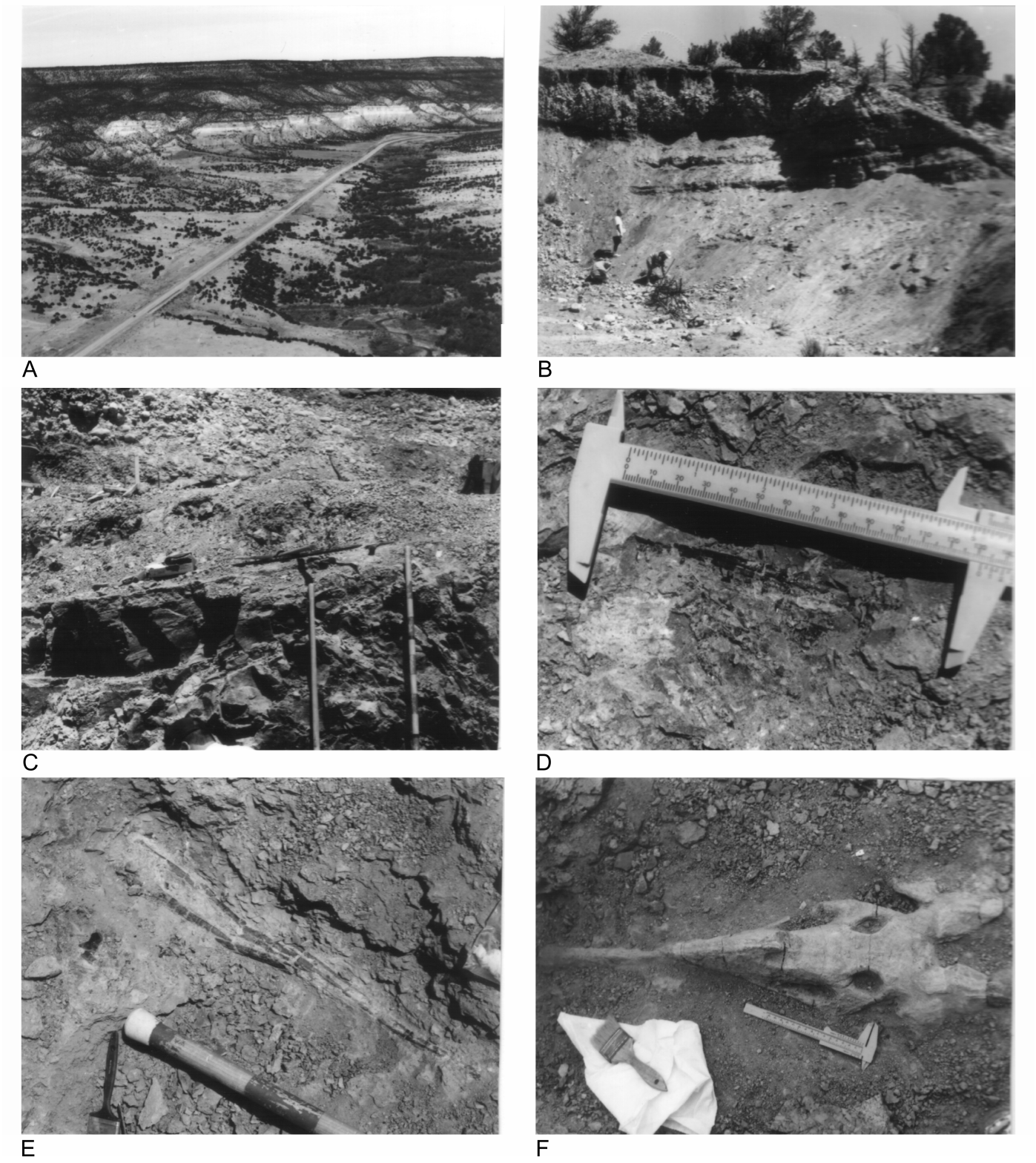

FIGURE 3. Geology and paleontology of the Snyder quarry. **A**, Aerial photograph of the Snyder quarry and vicinity, the quarry lies near the center of the photograph west of U.S. 84 (prominent road) and the "Monastery Road" (turnoff to left). **B**, The Snyder quarry as it appeared on 13 May, 1999, all excavation to that point had been conducted under the cliff wall in the shade of the right side of the photo. **C**, Depositional dip on "level 2" at the southern edge of the quarry (surface above staff and tool handle) compared to flat-lying level 3 in upper third of photograph. **D**, theropod jaw (NMMNH P-30852) as seen in the field, 19 May, 1999; **E**, phytosaur jaw (NMMNH P-36051) as seen in the field, 18 May, 1999; **F**, "George," a subadult male skull of the phytosaur *Pseudopalatus* (NMMNH P-31292, see Zeigler et al., 2002e), as seen in the field circa 27 May, 1999.

microstratigraphic section figures referred to earlier (Fig. 1).

Finally, by May 17 the crew was working in the main bone layer, completing jackets 9 and 10. We strung a baseline and completed a 1x1 m grid by 18 May. On 19 May we began to collect screenwash matrix, mainly by bagging up sediment from the trenches around potential jackets. Presently, only a fraction of this matrix is washed and still less picked, yet it appears rich and will increase our understanding of the diversity of vertebrates at the quarry. The most rewarding part of the day, however, was when NMFOP member Richard Wittie discovered a theropod jaw, which we quickly encased in jacket 11 (Fig. 3D).

Over the next few days we would continue excavations on a variety of fronts. A phytosaur jaw was excavated (jacket 16; Fig. 3E), and unionid bivalves were discovered on level 3 on 21 May. On Saturday, 22 May, a rainstorm swept in the mid-afternoon, chasing off much of the crew who had driven up for the day. The next day, 23 May, was the first day where we found phytosaur skulls. My father, Dave Heckert, found one (NMMNH P- 36000) at the northwestern edge of the quarry, and NMFOP member Larry Rinehart discovered another one (NMMNH P-31292) near the southern edge of the quarry workings. Unfortunately, the temperature suddenly dropped, rains came in, and much of the day was lost. Indeed, my field notes indicate that the day was so cold and wet that the remaining crew drank hot chocolate instead of beer that night.

John Fleck and Adolph Pierre-Louis of the Albuquerque Journal arrived in the mid-morning of 24 May and interviewed Snyder and I right after we completed jacket 18. Unfortunately, neither of the phytosaur skulls was really visible at the time, and the other noteworthy specimens were all in jackets. The crew was down to five members, the lowest we ever had that trip. Still, Fleck wrote a fine article on the site that appeared shortly after our return to Albuquerque (Fleck, 1999).

We brought Virgil Trujillo and the Ghost Ranch bulldozer back late on Monday to continue working down the Chinle overburden to the bone layer (Fig. 2C). Unfortunately, Virgil struck the reddish-brown mudstones *underlying* the quarry well above the level I expected. I will forever remember Mark Snyder waving at Virgil to stop the bulldozer as he (Snyder) dove onto the spoil being pushed by the bulldozer, rescuing a proximal phytosaur ischium and other bones from destruction and burial, all in a cold rain. Indeed, the rain on 24 May was heavy enough that the wash below the Snyder quarry ran, temporarily marooning us at our campsite on the far side of the wash from Monastery Road.

For the remainder of the trip, rain would be a recurring theme. All told, it rained nine days in a row, eight times during part to all of the day, and on the ninth occasion at night as we ate. Still, we began to encounter more (and more frequent) aetosaur material, principally scutes of *Desmatosuchus*. I originally thought one of these was referable to *Paratypothorax*, but I was mistaken. Jackets began to form up faster, in spite of our ongoing battles with the weather. By this time we had discovered that the soft intraformational conglomerate that underlay much of the quarry did, in some places, grade into a 15+ cm thick, hard siliceous conglomerate and sandstone that was difficult to cut through. This hard layer did, however, make an outstanding base for jackets.

On 30 May the crew was especially large, its ranks swollen by NMFOP members joining us for Memorial Day weekend. At this time we finally had enough people to work the quarry on two fronts, the main SE-NW trend of the original outcrop face and a second, WSW-ENE trend made possible by the bulldozing. Almost immediately after starting on this second front various volunteers found scutes of the aetosaur *Typothorax*, a relief to me as, stratigraphically, we expected to find this Revueltian index taxon, but until then had not seen its distinctive armor. This was a big jacketing day, too. Jacket 29 held the phytosaur skull Rinehart discovered, now beautifully exposed and obviously complete (Fig. 3.5, see also Zeigler et al., 2002, 2003), and three other jackets, one of which (jacket 32) was a monster—probably at least 1000 lb.

Somehow we flipped jacket 32 with a crew of only 5 people the next day before we packed up camp and returned to Albuquerque (Fig. 2D). We had to leave a very complex deposit on the northwest side that included phytosaur skull, limb, and rib elements. We buried this deep beneath padding, lumber, and spoil, as we would return for this potential jacket later. When unloaded at NMMNH, the assembled fossils, including 24 new jackets and boxes and boxes of isolated bones, matrix blocks with invertebrates, and other fossils, covered 7 pallets on the annex floor of the NMMNH.

I arranged the return excavation for September of 1998. The rest of my field season was taken up with dissertation and related research, and after nine days of rain in May there was no way I wanted to try to excavate a particularly difficult jacket during monsoon season.

In August, 1999, KEZ matriculated at UNM, ostensibly to undertake a paleobiology/stable isotope thesis. By September Spencer Lucas asked me "isn't there a paleontology project we can throw this girl at?" Knowing that (1) my dissertation research would preclude me giving the Snyder quarry the attention it deserved for the next few years, and (2) my attempts to map the deposit and the material coming from it could most charitably be described as "crude," I noted that we desperately needed a geoscientist to explore the sedimentology and taphonomy of the Snyder quarry

Regardless, I arranged to drive the NMMNH HMMV (Humvee) up on 16 September, meeting Mark Snyder at the site. I drove up in the dark, driving though one of the most spectacular lightning storms I had ever witnessed. Work the next day was marred by rain showers, but the crew was large and getting larger, allowing us to continue work near where jacket 32 came out as well as focus on the large block that stymied us in May. On Saturday, 18 September, KEZ made her first trip to the site, riding up with Larry Rinehart. That was probably the largest crew ever assembled at the Snyder quarry—26 people worked at the quarry that day, making all or part of five jackets (and two more the next day). Jacket 37, the large one in the center of the bonebed, finally came free late on Sunday, thanks in large part to the use of the Rondan Jacket Clamp (see Peterson et al., 1999, 2000).

That trip was important—not only did we recover seven more jackets in just three days, secure more *Typothorax* scutes, phytosaur skulls, and theropods, but it allowed us to plan for the next year. Even more importantly, it led Kate to ask a few questions—(1) if the Snyder quarry was part of my dissertation (no) and (2) if anybody was working on the sedimentology or other aspects of the site (again, no, but we would sure like you to). KEZ had demonstrated a great deal of skill and talent, not just in excavating (she was a veteran of several Earthwatch digs here and abroad) but also in working with me and our volunteers as part of a team. I was convinced that she had the aptitude to continue excavating with us, and reported to Spencer Lucas that there was indeed a project to "throw at her."

Two other important things happened for the Snyder quarry in 1999. At the fall 1999 Society of Vertebrate Paleontology (SVP) meeting, I presented an abstract on the Snyder quarry (Heckert et al., 1999b) in the "Bonebed Symposium" at that meeting and, two days later was thrilled to receive the SVP Bryan Patterson award, which would fund much of the next summer's excavations.

KEZ lined up an even more ambitious dig schedule for the next summer, another 17 day trip, a week-long "detail dig" to map the quarry in exquisite detail, and another 14 day dig to close it out, all between late May and early July. We would co-run the first two weeks, then it was "her baby," although I would come back to help close it down.

For once the weather would cooperate, although in 2000 it was so dry that National Forest restrictions prevented us from using campfires for the whole field season. Indeed, slightly more than a week before we planned to return to the Snyder quarry, the Forest Service lost control of a "controlled burn," the Cerro Grande fire that burned parts of Los Alamos.

The first dig, 23 May-8 June, started right as the Cerro Grande fire was winding down. This blaze, and others, very nearly prevented us from reaching the site due to road and forest closures. Still, we were able

to reach the site on 23 May, brining a rented miniature backhoe (Terramite®) provided at a deep discount by Frank's Rentals in Albuquerque. For the next week we would work with two bulldozers (the Ghost Ranch machine broke) and the Terramite®, while continuing to excavate everywhere across the main bonebed.

Summer 2000 Excavations (KEZ)

In the fall of 1999, I arrived in New Mexico, fresh out of college and looking forward to beginning graduate work in paleontology at the University of New Mexico. When the project I was initially assigned to began to look a little dubious, I asked Dr. Spencer Lucas for advice on the possibility of a new thesis project. I had been to the Snyder quarry on a weekend dig over Labor Day weekend, led by Andy, but did not really know what to make of it. After all, my rather nebulous future plans revolved around paleontology in general, but nothing specific. I did not yet have a specific idea of what I wanted to focus on. Spencer suggested, over a brown bag lunch in Tigeux Park, that I switch my thesis project to a taphonomic analysis of the Snyder quarry. Not really having a clue what the term "taphonomy" meant, I agreed and during the winter of 1999-2000, I began to research taphonomy and began planning a lengthy excavation for the summer of 2000.

On May 22, 2000, we loaded up the museum's fifth wheel horse trailer with enough plaster, burlap and tools for a five week stint at the quarry. I was very excited to get going, having listened to Andy's stories of his previous excavations. On May 23, the crew arrived from diverse directions and at various times throughout the day. Among the crew members was Scott Myers, an undergraduate from my alma mater Rice University, who would become my field assistant. Over the next two weeks, Andy and I, together with a multitude of volunteers, began opening up the Snyder quarry on a grand scale. My goal for the summer was to open up as much of a continuous surface of the bonebed as possible, in order to create a detailed quarry map. Accordingly, as more fossils were exposed, I began to lay out a grid from the same marker point that Andy had used to create a rough grid to make positions of the jackets he removed in previous excavations.

Initially, I tried to lay out a tidy grid using neon pink cord, but after seeing the grid get ripped up by shovels, feet and the Terramite, I gave up on that idea and instead drove nails in to the matrix of the bonebed at every corner of the square-meter grid across the quarry surface. I tied bright blue and bright pink flagging on the nails with a grid identification label written on each. While we still lost the occasional nail to shovels and feet, their attrition rate was much lower than for the cord. With Andy's help, I also began taking strike measurements on all the long bones as they were excavated. It was during the first week of excavations that we became aware of a small normal fault running through the middle of the quarry with a western dip to the fault plane. The 0.5 m offset caused some consternation before we realized what it was. Now that we were finally able to expose large areas of the bonebed at a time, we were also beginning to recognize that, in many cases, the bones were associated, and not completely disarticulated. We were also slowly uncovering a mass of tangled, overlapping *Typothorax* scutes, and we had uncovered a large phytosaur skull (nicknamed Mama) with several vertebrae around it.

By May 29, several pieces of data were already evident and I jotted down a list in my field notebook:

"- strong orientation of long elements

- very little articulation or association except for Mama phyto and some coelophysoids

- wood has perpendicular micro-cracks with lots of sulfur > evidence of burning?

- wood and bone intermingled - bone wedged in wood? or vice versa?

- rare individuals rather common (terrestrial mixed w/semi-aquatic)"

One of these points, the wood with microcracks, would turn out to be the key to the story of Snyder quarry, but at the time, I was not at all certain of what the excavations were beginning to show us. By June 1, we were beginning to jacket what had been uncovered to that point. From May 23 to June 1, jackets 42 through 44 were made and removed. Given the sheer amount of material in the bonebed, and the hard sandstone under the main part of the bonebed, trenching around a jacket was *very* slow going.

By June 4, a story was beginning to form in my mind. After discussing everything with my father over dinner the previous evening, I wrote out bits and pieces of the scenario in a rather disjointed way:

"- an eddy or backwater with debris and bones accumulating in it (like a good fishing pond)

- perhaps an overbank cut with trees collapsing into stream?

- fire > hydrophobic soils > wash carcasses into stream w/wood > drying? > congregating animals?

>> oxygen-consuming fire suffocates critters?

- bones all on east side of wood - wood wedge in perpendicular to stream and bones lodging against

- carcasses dead, ~decayed before entrained in stream"

On June 5, Mark Snyder and Scott went across US Highway 84 to check out directions to more fossils that were given to us by a visitor who had stopped by earlier. This visitor remembered finding black bones in a little arroyo when he was a little boy roaming the area. Mark and Scott found a "whole mess of blue/grey bones ~60' from little stream." After examining it and with great excitement, we declared it a continuation of the main Snyder quarry bonebed. Andy and I measured a short stratigraphic section and set the crew to removing what we could, as we had no intentions of waging a war on two fronts. We returned to the main deposit and by June 9, jackets 45 through 49 were made and removed. That afternoon, we loaded up most of the jackets and gear, backfilled the quarry and prepared to head back to Albuquerque early the next morning.

On June 13, I resumed excavations with the intent of really opening up as much continuous bonebed as possible to the west in order to get as detailed a quarry map as possible. Andy had left for Arizona and I was in the lead for the next two weeks. Spencer joined us that day to see the quarry and on the following day, he and I measured four detailed microstratigraphic sections at different points along the quarry's highwall. In the course of the stratigraphic work, we decided that the finely laminated, "swirly" mudstones above the main bonebed were lake deposits that had experienced some soft-sediment deformation, and that the three bone-bearing layers were either channels or were times when heavy floodwaters were channelized across the floodplain.

By June 17, we were beginning to see more topography on the bonebed surface, possibly representing channel forms like point bars and deeper channel trenches. We also uncovered a massive log running through the central trench. On June 18, most of the crew again returned to Albuquerque for a brief break and to gather more supplies. Scott stayed at the quarry to keep the bonebed open and to keep an eye on both the quarry and camp. Excavations began again on June 21, with the goal now being to remove as much material in jackets or otherwise as we could before the monsoon season began. I continued to map every bone and large chunk of charcoalized wood that was uncovered as we raced to beat the rains. Those who began excavating on the eastern side of the large log quickly grew very frustrated upon finding nothing but bits and

scraps of bone. This frustration led to discussion which led to the hypothesis that the large log had acted as a barrier to flow, causing the water to pile up, flow more quickly over the log and scour out the sediments beyond. We were beginning to see clouds building up to the south in the afternoons and were occasionally hit with light drizzles, a sure sign that monsoon season was getting ready to start.

On June 24, two British students, both conveniently named David, arrived at camp, minus their luggage thanks to the airlines. They would be with us for the rest of the summer in order to learn excavation techniques and to do research at NMMNH. By the 27th, rains were setting in nearly every afternoon and they were heavy enough that we were having to strike the tarps that were shading the quarry and wait it out in our tents. This made excavating extremely frustrating, as absolutely everything was soggy all the time. Glue was not setting, plaster was not firing and everyone was sliding around with three inches of mud on their shoes. Both Scott and I abandoned all pretense of wearing shoes. On the 27th, we needed to start jacket 50, but the Davids were quite nervous about their first plastering experience. In order to give them practice, we brought up a three week old watermelon left by a previous volunteer. Scott and I set it on a pedestal of dirt and with a bit of relief, the two Davids created their first jacket.

On July 1, Andy rejoined us to make the final push to close the quarry. By this point we had a dozen or more people working at any given time, making for moderately cramped quarters beneath the tarps. Several more phytosaur skulls had been excavated, including two large ones in the central trench, though we did not initially realize that one was a skull: "The 'lower jaw' of Phyllis is in fact, the top of Phineas. Oops." We had earlier taken to naming the phytosaur skulls for our own entertainment and to keep them all straight. In order of discovery during the 2000 field season: Phydo, Mama, Phred, Priscilla, Phyllis, Phineas, Phidel and Phievel. From July 1 to July 4 when we pulled out, we created jackets 53 through 62. The last two jackets were the most difficult to complete and remove. Jacket 61 was the *Typothorax* scute mess that had been continuously worked on from the very beginning of the 2000 excavations. Jacket 62 contained Phyllis (now Philip, as we consider pseudopalatine phytosaurs sexually dimorphic—see Zeigler et al., 2002) and Phineas and was in a very narrow trench, which made removing the jacket tricky.

Upon our return to NMMNH on July 5, with a summer's worth of strenuous excavations behind us, we tallied up all of the work that had been accomplished. Sixteen m^2 of continuous bonebed had been uncovered, mapped and excavated, and 20 jackets of various sizes had been removed, as well as over a dozen boxes of individual bones.

Summer 2001 Excavations

During the following summer, as the vice president of field affairs for NMFOP, I decided to use the Snyder quarry as part of a two-weekend field course for new volunteers. Beginning on May 15 through May 20, we started the course with general lectures on regional stratigraphy and sedimentology and learned orienteering. I had the volunteers fan out over the surrounding land to prospect for more fossils. I was not expecting to find much of anything, given that Andy's crews had searched the area previously. So it was a welcome surprise when the crew began finding scraps of charcoal at the same level as the Snyder quarry in the surrounding hills. We also prospected on the other side of US 84, without much luck, and across Monastery Road, with limited success.

On May 25th, we started the second half of the course, which was learning excavation techniques. I set up half the crew in the southern pit, with a few old hands to help out and set the other half to work in the western pit. Fortunately, I managed to relocate an old nail with a bit of flagging on it and was able to reconstruct my original grid system to incorporate the new finds into the existing quarry maps. Jackets 63 and 64 were removed, and a half-dozen boxes were filled with loose fossil material. Excavations ended on May 27, and the quarry was back-filled for semi-permanent closure.

PUBLICITY AND PUBLICATIONS ON THE SNYDER QUARRY

Throughout the excavation of the Snyder quarry we have all but shunned media attention. More important to us is the more permanent "fame" accorded the Snyder quarry in our diverse publications on it. Still, the science of the Snyder quarry has seen light through the popular media via fine articles in the Albuquerque Journal (e.g., Fleck, 1999) and even got a brief mention on the NBC Nightly News in 2000.

As the preceding narrative documents, we have worked to integrate the Snyder quarry into the professional literature from the very beginning. By 1999, the quarry entered the professional literature through the abstracts of professional meetings (Heckert et al., 1999a,b, 2000a). Later, Zeigler's work on taphonomy resulted in more abstracts (Zeigler et al., 2000a,b, 2001, 2002a,b), her thesis (Zeigler, 2002), and several papers, including one in this volume (Zeigler et al., 2002c; Zeigler, 2003). The systematics of various groups were also addressed from the outset. The dinosaurs were featured in an early abstract (Heckert et al., 1999c) and the first paper published on the Snyder quarry (Heckert et al., 2000b). The aetosaur records from the Snyder quarry also saw light in early abstracts (Zeigler et al., 2000c) and a paper naming the new species *Desmatosuchus chamaensis* (Zeigler et al., 2002d). Zeigler et al. (2002e) finally pinned down the identification of the phytosaurs as *Pseudopalatus*, something we had long suspected but, due to the vagaries of phytosaur taxonomy, had been difficult to ascertain. The invertebrates were also featured almost from the outset (Heckert et al., 1999b; Rinehart et al., 1999a, b, 2003). All of these groups, and more, are now featured in diverse articles in this volume (e.g., Heckert et al., 2003a,b; Lucas et al., 2003a; Zeigler et al., 2003a,b,c) as is the regional and local stratigraphy (Lucas et al., 2003b), the taphonomy of the quarry (Zeigler, 2003a), the sedimentary petrology of the quarry (Tanner et al., 2003) and more.

SIGNIFICANCE

Why does the Snyder quarry merit this abundance of effort? As the diverse papers cited here, and indeed this volume itself, testify, the Snyder quarry is truly a world-class locality. This singular quarry, or *Lagerstatte*, yields remarkable insights into a brief interval of Triassic time, perhaps as little as a few days or weeks of the Revueltian (early-mid Norian). Indeed, this is one of the oldest paleowildfires known, and the oldest one with unambiguously associated vertebrate fossils. This is not to say that we are positive that the animals in the Snyder quarry met their demise at the hands of a paleowildfire, but there is certainly an abundance of circumstantial evidence pointing to that possibility.

Beyond the relatively unusual mode of preservation, the mass death assemblage at the Snyder quarry has many other scientifically invaluable ramifications. Here, in the tangled mass of bones strewn amongst charred logs is one of the most diverse and abundant fossil assemblages known from the Triassic of the American West. The excavations we documented here are already sufficient to rank the Snyder quarry as one of the most diverse, prolific, and important Upper Triassic faunas in the world. The papers in this volume compile our knowledge of all aspects of the geology and paleontology of the quarry as we have sought to deliver the most complete synthesis possible.

The most common tetrapods at the Snyder quarry are phytosaurs, aetosaurs, and dinosaurs. Already the fossils of all three of these groups have inspired new scientific discoveries. It was in preparing to study the Snyder quarry phytosaurs that we stumbled across the obvious sexual dimorphism in the contemporary Canjilon quarry sample (Zeigler et al., 2002f). The Snyder quarry is the type locality of *Desmatosuchus chamaensis* (Zeigler et al., 2002d), and has helped us learn much of aetosaurs. There is no other locality in the world that yields more Revueltian theropod dinosaurs than the Snyder quarry, and the remarkable preservation of the theropods only increases their scientific value.

To be sure, this volume will not be the last word on the Snyder quarry. There are more fossils to prepare, and, if an immensely larger

effort is invested, even more vertebrates could be recovered from the quarry. Indeed, to the best of our ability to determine, the quarry's potential is effectively limitless. This paper simply documents what has been attempted, and accomplished, thus far.

ACKNOWLEDGMENTS

As we amply document here, this work would have been impossible without the determination and effort of volunteers too numerous to list here. We are especially indebted to the New Mexico Friends of Paleontology and other NMMNH volunteers for the time and effort necessary to excavate, collect, prepare, and catalog the fossils from the Snyder quarry. Funding from the Society of Vertebrate Paleontology (Bryan Patterson award to ABH), New Mexico Geological Society (Grants-in-aid to KEZ), and the New Mexico Friends of Paleontology supported work at the Snyder quarry. Kim Murphy of the UNM Real Estate office premitted our excavations at the Snyder quarry. The New Mexico Museum of Natural History provided logistical support. S.G. Lucas printed the photographs published here, and read and improved an earlier draft of this manuscript with his comments.

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APPENDIX

Excavation, preparation, and collection crews at the Snyder quarry.

Excavation Crews of 1998

First dig:

Alex Downs (GR), Adrian Hunt (MDM), and the Ghost Ranch program "Digging dinosaurs at Ghost Ranch" (14 participants).

Second dig:

Alex Downs, Jerry Harris, Liza Hartmann, Charles Jaynes, Allan Lerner, Herb Palm, Mike Pierce, Pete Reser, Larry Rinehart, Scott Sucher.

Excavation Crew of 1999

Sheila and John Bednarski, Pat and Allan Burke, Kristan Cockerill, Brendan Cohen, Alex Downs, Wes and Sally Estill, Gordon Gluck, Jerry Harris, Susan Harris, Sarah Hartshorne, Liza Hazanoff, Dave Heckert, Paula, Bill and Justin Holub, Margie Homko, Dan and Louise Howe, Charles and Nicole Jaynes, Sally Johnson, Richard Krukar, Allan Lerner, Shirley Libed, Gwen Lindquist, David McCarthy, Bruce and Evan Moore, Gary Morgan, Ron Morgan, Mike Najdowski, Roy and Doria Nelson, Tracy O'Kelly, Jeff Ortiz, Herb Palm, Ron Peterson, Mike Pierce, Clayton Pilbro, Pete Reser, Larry Rinehart, Warren Slade, Mark, Michael and Mary Snyder, Scott and Karen Sucher, Tom and Maggie Sucher, Armand Tabor, Jessica Thompson, Ben Umbreit, Richard and Mandel Wittie, Jason Wilburn, Steve Yesner, Lindsay Zanno, Fecundo.

Excavation Crew of 2000

Sheila Bednarski, Sandy Bruschini, John and Diane Carnell and nephew Jason, Kristan Cockerill, Mike and Sandie Cockerill, Wes and Sally Estill, John Foster, Susan Harris, Dave Heckert, David Jones, Allan Lerner, Shirley Libed, Gwen Lindquist, Spencer Lucas, David McCarthy, Ron Morgan and family, Scott Myers, Mike Najdowski, Herb Palm, Larry Rinehart, Mike Shaver, Mark Snyder, Scott and Karen Sucher, Herb Palm, Mary Alice Root, Jason Wilburn, Richard and Mandel Wittie, Edwin Yau, Lindsay Zanno, Paul and Ann Zeigler, Fecundo and nephews Sage and Justin, Dave and Aaron (FoP).

Excavation Crew of 2001

Jesse Baldwin, Sandy Bruschini, Sandra Bybee, Kathleen Hall, Peggy Hulick, Shari Hanson, David McCarthy, Dave Mehlmann, Jackie Melton, Anne-Marie Peck, Bob Rogers, Vera Snyder, Scott Sucher, Richard and Mandel Wittie, Paul Zeigler.

Preparation crews

Sandy Bruschini, Pat and Allan Burke, Sandra Bybee, Clarke Condé, Dan D'Andrea, Joe DiBenedetto, Steve Gantz, Shari Hanson, Kash Heitkamp, H.R. Humphrey, Dave Justice, Hillary Jenkins, Gwen Lindquist, Rolf Lindquist, Dave McCarthy, Bud Newman, Bill Ortman, Dawn Ranelli, Ruth Ann Peterson, Larry Rinehart, Leo Seese, Scott Sucher, Vera Snyder, Renita Trujillo, Richard Wittie.

Collection crew

Hillary Jenkins, Jane Sandoval, Justin Spielmann.

The crew under tarps at the eastern end of the quarry during July 2000 excavations at the Snyder quarry (photograph by A.B. Heckert).